

Data Variability in Arthropod Samples Used for the Biotic Index¹

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Abstract

Factors that influence the reliability of the biotic index (BI) for evaluating the water quality of streams include sample size, substrate sampled, current, method of processing samples, water temperature, time of the year, and level of arthropod identification. Comparison of standard deviations of sample sizes of 50, 100, 150, and 200 indicated that a sample of 100 was adequate for most evaluations. By sampling only riffles, differences in substrate and current were minimized, and differences between riffles in the same stream were not substantial enough ($SD=0.25$) to alter evaluations made with the BI. Biases were found in samples picked in the laboratory as well as in those picked in the field, but these biases had little effect on the BI. By processing samples in the laboratory more valuable field time is made available. The greatest variability in BI evaluations resulted from seasonal differences in the fauna, with index values being abnormally high in late spring or summer. Much time can be saved by evaluating streams with a family-level biotic index, but precision is lost and the ability to discriminate between various levels of pollution is diminished.

Key Words: Biotic index, Water quality, Pollution, Arthropods, Insects, Data variability, Sampling, Sample bias, Streams

Introduction

In 1977 I recommended using a biotic index (BI) of the arthropod fauna to evaluate the water quality of streams. This index was based on a sample of 100 or more arthropods that were collected with a net from the riffle area of a stream (Hilsenhoff 1977). Species (or genera when species could not be identified) of stream arthropods were assigned tolerance values of 0 to 5, depending on their tolerance to organic pollution, with the most tolerant organisms having a value of five. The BI is the average of tolerance values for all species of arthropods in a sample. After five years tolerance values were revised and several studies relating to sampling procedure and data variability were completed (Hilsenhoff 1982). More recently data from more than 2,000 stream sites were used to further revise tolerance values and a 0 to 10 scale was introduced to increase precision (Hilsenhoff 1987). Since

tolerance values of 0 to 10 are assigned to each species there are only 11 categories of arthropods that are used to calculate a BI. This results in less data variability than when several dozen different species are available for collection. A discussion of important factors that introduce variability into the BI follows.

Sample Size

Kaesler and Herricks (1976) found that a sample size of 100 was adequate for evaluation of stream samples with a diversity index. Two sets of six samples of 50 arthropods from Armstrong Creek, Wisconsin were combined in all possible ways to produce three replicated samples of 50, 100, 150, and 200 arthropods (Hilsenhoff 1982). As sample size was increased, standard deviations decreased (Table 1), but when evaluating streams with the BI the gain in precision from a sample of more than one-hundred probably does not justify the extra time needed to

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Table 1. Standard deviations of biotic index values in relation to sample size from two sets of six samples of 50 arthropods, combined in all possible ways to produce samples of 100, 150 and 200. Samples were collected from the same riffle in Armstrong Creek; one set was one picked in the field and the other was picked in the laboratory.

Sample Size	Number	Standard Deviation	
		Field-Picked	Lab-Picked
50	6	0.213	0.347
100	15	0.124	0.205
150	20	0.085	0.146
200	15	0.062	0.103

collect and process a larger sample. If greater precision is desired, replicated samples are recommended.

Sampling Site Differences

Three different riffles in each of six streams were sampled at two-week intervals from April through November in 1984 and 1985 (Hilsenhoff 1988a). The standard deviation of 32 sets of 3 samples from each stream was 0.25 and the 95% confidence limits were + 0.48 (Table 2).

Table 2. Standard deviations (SD) and confidence limits of biotic index (BI) values of samples collected from three different riffles in each of 6 streams on 32 dates over a two-year period.

Stream	BI	Confidence Limits		
		SD	95%	99%
Otter Creek	2.24	0.26	+0.50	+0.67
Trout Creek	2.29	0.33	+0.65	+0.85
Sugar River	4.91	0.26	+0.50	+0.67
Pecatonica R.	5.48	0.25	+0.49	+0.64
Narrows Creek	6.08	0.20	+0.38	+0.52
Badfish Creek	6.46	0.14	+0.28	+0.36
Average	4.58	0.25	+0.48	+0.63

Differences in substrate and current are most likely to affect the fauna; areas with slow currents, especially,

tend to be inhabited by insects that are more tolerant of low dissolved oxygen levels and organic pollution. When the BI of three riffles in each of six streams was compared (Hilsenhoff 1988a), significant differences were found in four of the streams (Table 3), but these differences were not great enough to substantially alter the evaluation of any stream. Differences did not appear to be related to current since the riffle with the slowest current had the highest BI value in two of the streams and the lowest in the other two. Most riffles have currents in excess of 0.5 m/sec, which is sufficiently fast so that arthropods will not be stressed in well-oxygenated water. Variability of substrate was most likely responsible for significant differences in the BI of samples from some streams.

Bias in Sample Picking

When arthropods are picked from a sample there is always a distinct bias that favors certain species. In a set of 12 samples from the same riffle in Armstrong Creek that were alternately picked in the field or preserved and picked in the laboratory (Hilsenhoff 1982) distinct biases in picking were obvious (Table 4); at the time the samples were picked I believed that almost every arthropod had been removed from each sample. Active arthropods tend to be preferentially picked in field samples, and if cryptically colored they are difficult to find among the debris in preserved samples. Inactive, cryptically-colored arthropods are difficult to see in field samples, but many change color when preserved in alcohol and are easy to find in the laboratory. Larvae of *Optioservus* (Elmidae) are an excellent example. When preserved in alcohol they often become distended, exposing white intersegmental membranes that are easily seen. Fortunately these biases usually do not have much effect the BI. In a study of five streams in which alternate samples from the same riffle were picked in the field or in the laboratory (Hilsenhoff 1982) only

Biotic Index Variability

Table 3. Analysis of variance of biotic index values of arthropod samples from three riffles with varying currents at low flow in six Wisconsin streams. Samples were collected at 2-week intervals from 18 September to 13 November 1985. (Reproduced with permission from the Great Lakes Entomologist.)

Stream	Current m/sec			Mean Biotic Index			SD	F
	1	2	3	1	2	3		
Otter Creek	0.42	0.53	0.75	2.08	1.83	2.06	0.27	1.37
Trout Creek	0.87	0.81	0.59	3.83	3.33	2.73	0.46	7.23*
Sugar River	0.47	0.38	0.56	5.27	5.62	5.19	0.24	4.49*
Pecatonica River	0.68	0.61	0.65	5.41	5.92	5.82	0.16	14.68**
Badfish Creek	0.48	0.64	0.66	7.11	6.87	7.08	0.17	3.12
Narrows Creek	0.81	0.81	0.71	7.85	7.41	7.13	0.32	6.36*

* P = 0.05 ** P = 0.01

Table 4. The amount of bias in laboratory- and field-picked samples.

Family or Order	Lab ^a	Number of Arthropods		Bias ^c Ratio	Bias Rank
		Field	Difference ^b		
Perlidae	96	142	+46	+1.48	6(+)
Baetidae	173	176	+3	+1.02	
Ephemerellidae	65	65	0	1.00	
Heptageniidae	40	57	+17	+1.43	8(+)
Other Ephemeroptera	38	38	0	1.00	
Odonata	12	14	+2	+1.17	
Brachycentridae	31	94	+63	+3.03	3(+)
Glossosomatidae	54	12	-42	-4.50	2(-)
Hydropsychidae	245	358	+113	+1.46	7(+)
Corydalidae	38	35	-3	-1.09	
Elmidae adults	38	84	+46	+2.21	4(+)
Elmidae larvae	264	36	-228	-7.33	1(-)
Athericidae	37	48	+11	+1.30	9(+)
Chironomidae	93	73	-20	-1.27	10(-)
Simuliidae	46	54	+8	+1.17	
Tipulidae	51	28	-23	-1.82	5(-)
Gammaridae	54	61	+7	+1.13	
Asellidae	200	202	+2	+1.01	

^a Adjusted so that laboratory-picked totals equal field-picked totals.

^b Laboratory-picked sample subtracted from field-picked sample.

^c Bias ratio is a ratio of the largest number to the smallest.

in the Mecan River was there a significant difference in the BI (Table 5). Here Optioservus larvae (tolerance value of 4) predominated in laboratory-picked samples, while the active but cryptically colored Brachycentrus americanus, B. occidentalis, and Ceratopsyche sparna (all with a tolerance value of 1) were

most numerous in field-picked samples. The BI varies most in very clean streams (Tables 2, 6), but since all values below 3.5 are considered to represent "excellent" water quality (Hilsenhoff 1987), these variations in the BI of clean streams are not important. Preserving samples and processing them in laboratory is

Table 5. Comparison of differences (t-test) between means of biotic index values of replicated field-picked and laboratory-picked samples from five streams. SD = standard deviation from the mean.

Stream	Field	Mean Biotic Index		t	SD
		Lab.	df		
Armstrong Creek	2.22	2.08	10	0.84	0.29
Badfish Creek	7.16	7.22	4	0.15	0.50
Mecan River	2.01	3.15	4	14.51**	0.09
Milancthon Creek	3.71	3.80	4	0.28	0.40
Poplar River	5.01	5.08	4	1.76	0.15

** P = 0.01

Table 6. Comparison of differences (t-test) between means of the biotic index (BI) and the family-level biotic index (FBI) of three replicate samples from six streams in mid-April, late-June, early-September and mid-November in 1984 and 1985. SD = standard deviation from the mean. (Reproduced with permission from the Journal of the North American Benthological Society.)

Stream	Year	Mean		t	SD	
		BI	FBI		BI	FBI
Otter Creek	1984	2.43	2.77	4.65**	0.22	0.30
	1985	2.62	3.27	4.90**	0.27	0.37
Trout Creek	1984	2.23	2.52	4.41**	0.45	0.54
	1985	2.61	3.18	4.84**	0.35	0.39
Sugar River	1984	5.49	5.13	7.28**	0.28	0.33
	1985	5.44	4.83	8.73**	0.23	0.28
Pecatonica River	1984	6.31	6.31	0.06	0.19	0.21
	1985	5.81	5.76	0.34	0.20	0.23
Narrows Creek	1984	6.68	6.15	6.67**	0.20	0.34
	1985	6.36	5.83	10.76**	0.18	0.20
Badfish Creek	1984	7.05	6.71	2.20*	0.17	0.30
	1985	6.77	6.24	6.08**	0.15	0.36
All samples					0.24	0.32

* P = 0.05 ** P = 0.01

recommended because much valuable field time is saved.

Seasonal Variability

A recent study (Hilsenhoff 1988a) showed that the greatest variability in BI evaluations resulted from seasonal differences in the fauna (Fig. 1). BI values were highest in summer when water temperatures were warmest, currents were slowest, and species that were collected were those

that are most tolerant of low dissolved oxygen. In warm-water streams a substantial rise (usually greater than 1.5) in the BI occurred in late May or June and lasted for about two months. In cold water streams this rise occurred in the summer and was of a lesser magnitude (about 1.0). The timing and magnitude of the late spring or summer elevation of the BI depends on spring temperatures and can be predicted by accumulation of degree days from a

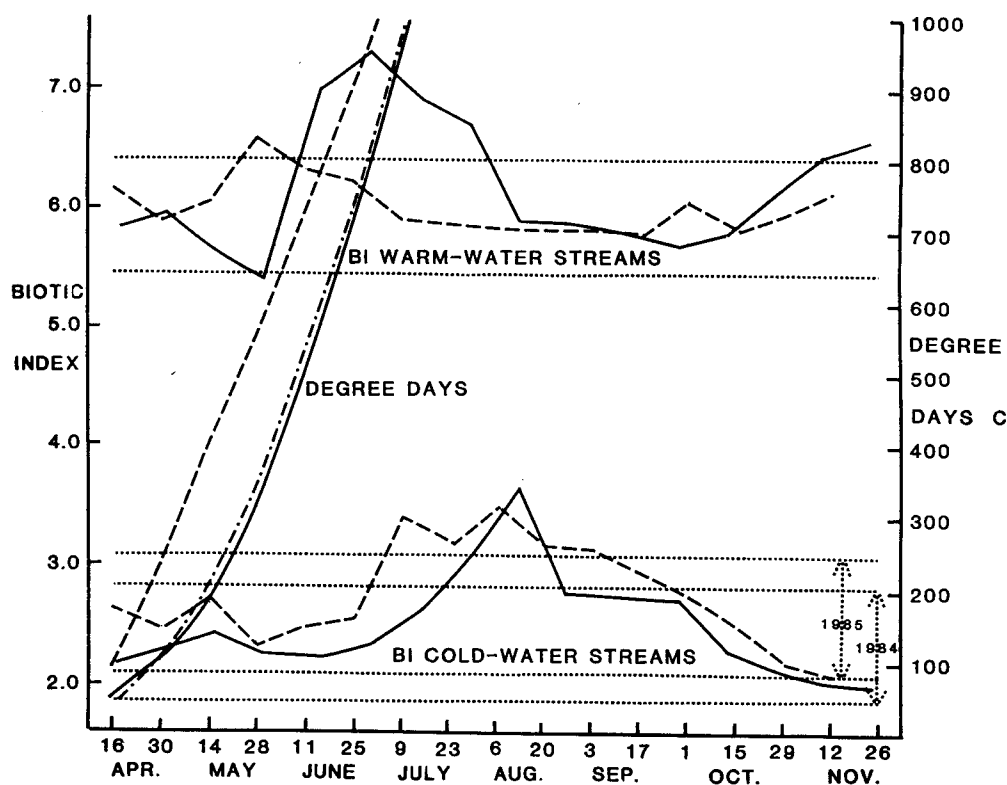


Figure 1. Mean biotic index values of four warm-water streams and two cold-water streams in 1984 (solid lines) and 1985 (dashed lines), with 95% confidence limits (dotted lines) for the mean of the lowest 75% of biotic index values. Comparison of degree day accumulations of mean air temperature above 4.5° C in 1984 (solid line) and 1985 (dashed line) with 1951-1980 average (dot-dash line). (Reproduced with permission from the Great Lakes Entomologist.)

base of 4.5° C (Hilsenhoff 1988a). Using the BI to evaluate streams during the summer months is not recommended.

Family-level Biotic Index

Evaluation of streams with a family-level biotic index (FBI) takes about one-fourth the time required for a BI evaluation that uses species and genera (Hilsenhoff 1988b). This saving of time, however, results in greatly reduced precision and there is a greater chance of making an erroneous evaluation. In organically polluted streams the FBI was substantially lower than the BI and in unpolluted streams it was higher (Table 6); standard deviations were always greater when using the FBI. However,

if FBI samples are preserved, a BI evaluation can always be completed at a later date.

Summary

If samples of 100 or more arthropods are collected from rock or gravel riffles at the proper time of the year, sample variability will be held to a minimum and the BI can be used to accurately evaluate the degree of organic or nutrient pollution that has occurred in the stream. Use of the FBI will save considerable time, but the evaluation will be much less accurate.

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